LIFE CYCLE COST ANALYSIS OF ONLINE DISSOLVED GAS ANALYSIS MONITORS

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ABSTRACT

A simple life cycle cost model for online dissolved gas analysers has been developed and is applied to two commercial instruments. Reliability data is derived from in-service performance. The work shows that on-going operation and maintenance costs have a significant impact on the total cost of ownership; in particular, the number of call outs required to facilitate repairs.

INTRODUCTION

Transformers are one of the key components of the electrical power system. Due to their high capital value and importance, transformers are prime candidates for continuous online monitoring to provide asset owners with confidence that their investments are performing as expected and free from developing defects [1].

Dissolved gas analysis (DGA) is the most common method for assessing the health of transformers due to its ability to detect and diagnose developing problems, and track the evolution of defects. Oil samples are typically taken annually and sent to a laboratory for analysis. For critical transformers or on units where frequent offline samples are required (for example to track a known defect), online DGA reduces uncertainty, offers peace of mind and may actually extend transformer operational life, delaying the need for large capital replacement expenditures.

Today there is a range of analysers on the market which:

- Detect the key gases in different ways
- Require different levels of maintenance
- May require consumables
- Have different accuracies and detection limits

These analysers also have different associated capital costs and levels of reliability. As such it can be difficult for asset owners to know which analyser represents the best option for their particular need. In all cases the cost of the analyser is an important attribute, but a low-cost analyser which proves to be unreliable, may prove to be costlier over the life of the transformer [2].

Life cycle cost analysis or total cost of ownership allows a range of factors (cost, maintenance, repairs, electrical losses etc) to be considered in a schematic manner in a variety of applications [3-5]. In the case of monitors, early experience however reveals that on-going Operations and Maintenance costs are significant and should be considered in the selection process.

Here we report on the development of a simple life cycle cost (LCC) model [6] and use it to compare two multi-gas instruments based on different analyser technologies.

LIFE CYCLE COST MODEL

A simple life cycle cost model has been developed which allows the major costs of owning and operating an online DGA to be taken into account. The factors in the model include:

1. Initial capital cost – hardware and site works
2. Consumables
3. Life expectancy
4. Repair costs – time and parts
5. Planning costs associated with site visits

The model applies each of these costs in a particular year and calculates the net present value (NPV). The model has been applied to two commercially available multi-gas DGA analysers.

Analysers for comparison

Two populations of commercially available online multi-gas DGA analysers are considered in this study. Analyser:

A. Is a gas chromatograph-based analyser which requires calibration and carrier gas,
B. Is an infra-red spectroscopy-based analyser which does not require additional gases.

It is beyond the scope of this paper to detail all the other differences in the respective specifications, but in general chromatography instruments tend to be more accurate and have lower detections limits but do require consumables, whereas infra-red instruments have a simpler design, don't use a calibration gas and tend to be lower capital cost.

Repair data and costs

Data for the analysis has been determined from Doble's records of installing and maintaining different DGA monitor populations for clients around the globe. Figure 1 shows a breakdown of the causes of interventions during operation for the Analyser B population. The failure cause categories are:

- Analyser – Failure of the gas detector
- Comms – Issues with the communication link to the online analyser
- Electronics – Faulty cards, power supplies etc
- Oil – Leaks, pump failures, manifold problems
- Miscellaneous

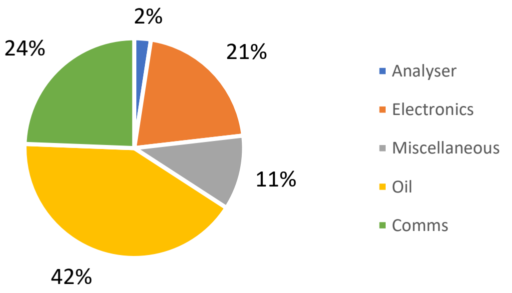

Figure 1: Relative distribution of the type of repairs required on Analyser B population.

The data are from a population multi-gas monitors operated by a large European transmission utility. The pie chart shows that the majority of the problems are associated with the oil circuit (42%) and the communications system (24%).

Given that the communications hardware/method is usually specified by the end user, and issues may be location specific (e.g. cell phone coverage), costs associated with fixing communication issues have not been included in the subsequent LCC analysis. Excluding communication repair costs from the analysis enables a fair comparison between different analyser populations.

Figure 2 also shows the repair cost breakdown once communication issues have been excluded for Analyser A and B. The pie charts have been scaled to the average annual repair expenditure on the two different populations. The average annual repair expenditure on Analyser A is less than one third that of Analyser B.

Analyser A has repair costs associated with the gases to run the chromatograph (e.g. leaks), which do not occur with the infra-red based system. It can be seen that the oil circuit accounts for over 60% of the repair costs associated with Analyser B, compared to only 15% for Analyser A. The detector in Analyser B is robust and has had a comparatively small number of issues leading to only 5% of the total repair costs. In comparison, the detector of Analyser A accounts for 41% of the average annual repair cost; this seemingly high value is in fact caused by a small number of costly repairs. Contrastingly the 61% of average annual repair cost for problems with the oil circuit of Analyser B is caused by many relatively low-cost fixes. Consequently, it is not just the cost of repairs which is important to consider but also the number of times intervention is required. Based on the available data Analyser B requires three times more repair activities than Analyser A.

Based on this analysis, the following parameters have been calculated for the two populations of analysers:

- Average repair hardware cost per analyser per year
- Average number of hours spent working on an analyser per year
- Average number of issues which require a site intervention per analyser per year

Model

This section describes the key parameters which feed into the model and explains the main functionality.

Figure 3 shows how some of these costs are distributed through time. This example represents a gas chromatograph-based analyser which requires replacement of consumable calibration and carrier gases every four years, thus these are required in year 1 (when the instrument is first installed), and subsequently in years 5, 9, 13 etc. Average annual maintenance and repair costs have been calculated based in performance data (see below) and applied in every year. The cost of repairs performed under warranty have been included in these average annual maintenance and repair values, since individual analyser owners may negotiate extended warranties with suppliers; such subtleties can be modelled but require detailed knowledge of the repair history.

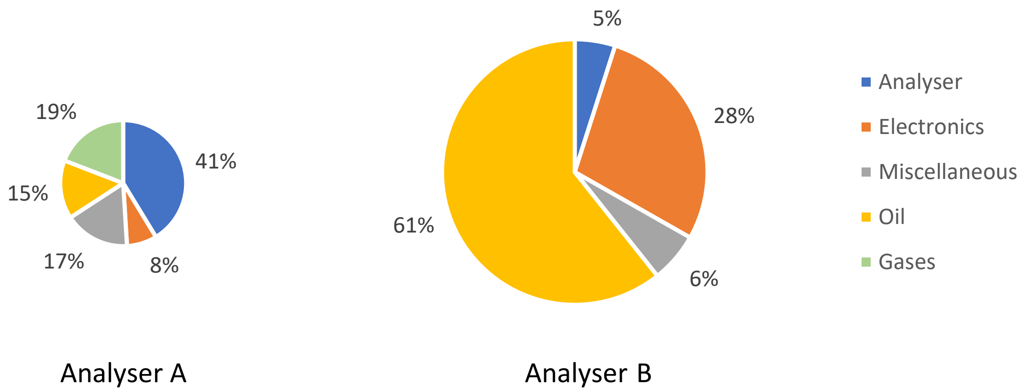

Figure 2: Pie charts showing repair cost breakdown (excluding communications). Pie chart area has been scaled to the average annual repair expenditure on the two different instruments.

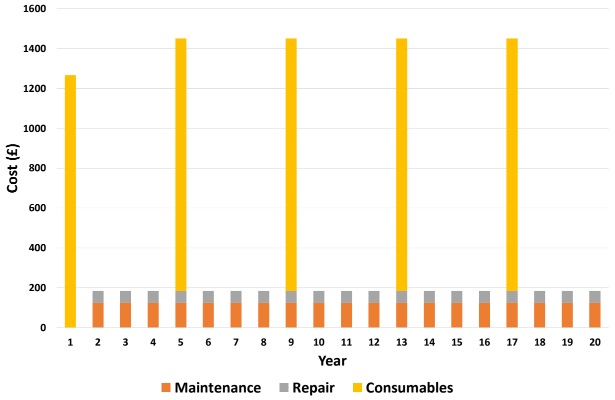

Figure 3: Distribution of costs through time for Analyser A

These costs accumulate throughout the life of the analyser (Figure 4). Each year annual maintenance and the calculated average annual repair cost are added. In the case of Analyser A which requires periodic gas bottle replacement, this cost is added every four years.

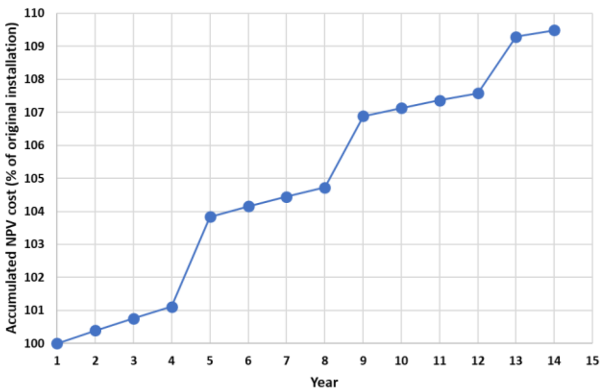

Figure 4: Accumulation of costs through time for Analyser A normalised to the initial installation cost, highlighting repairs and consumable costs.

Within the model the instrument is replaced at a predetermined interval based on the expected life. For Analyser A this is based on the manufacturer's life expectancy expected (15 years), and for Analyser B, this is based on field experience of the population installed at the European transmission utility and also feedback from clients in the US (10 years).

Figure 5 shows the impact of replacing Analyser A after 15 years to the accumulated NPV. Due to the difference in life expectancy of the two instruments, the total cost of ownership is calculated over an extended period of several life cycles; in all the results presented here, this has been 30 years.

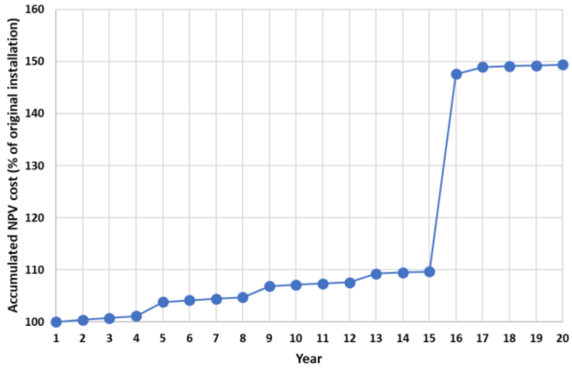

Figure 5: Accumulation of costs through time for Analyser A normalised to the initial installation cost, highlighting periodic analyser replacement.

RESULTS AND DISCUSSION

Based on the repair cost data, number of repair interventions required, consumable costs (if required) and the expected lives of the two analysers, Analyser A is found to have the lower life cycle cost despite the higher initial capital cost and need for periodic consumables.

Figure 6 shows that ignoring the travel time for a specialist service engineer to attend and repair a faulty analyser, Analyser A delivers approximately a 16% saving compared to Analyser B. This is a significant potential saving. This saving increases with travel time; up to 19% when the journey time becomes four hours.

What is not considered here is the internal costs to the analyser owner of their staff time to be available at the analyser location during the repair. Some sites may be manned thereby minimising this cost, however at unmanned sites requiring staff travel there are additional costs not captured by the model. As such these results are minimum savings since they underestimate the internal costs born by the analyser owner: such figures could be incorporated in a study focused on a particular client.

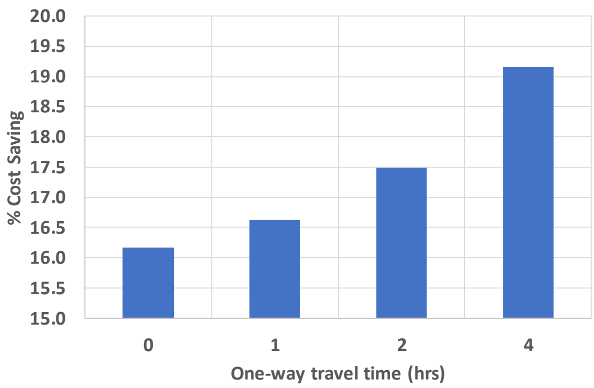

Figure 6: Life cycle cost saving of the chromatography based analyser compared to the infra-red instrument as a function of engineer travel time to carry out repairs.

The simple nature of the model allows the sensitivity of the output on various parameters to be explored. Figure 7 shows the results considering the life expectancy of Analyser B as a variable.

The x-axis denotes the assumed life of Analyser B (increasing from the 10 years used in the examples above). The y-axis shows the difference in life cycle cost relative to Analyser A based on a 15-year life. Consequently, positive y values indicate the Analyser B is more expensive than Analyser A over the period used in the model; negative y values indicate the Analyser B is the lower life cycle cost.

As the assumed life of Analyser B increases the cost saving delivered by Analyser A is eroded. When the assumed life of Analyser B is 14 years, Analyser A still represents a 7% cost saving over the life cycle. However, when the life of Analyser B is extended to 15 years and beyond it becomes the cheapest total cost of ownership. The discontinuity in the plot between 14 and 15 years is caused by a change in the number of life cycles occurring in the 30 year period of the analysis; two for Analyser A (fixed 15 year life in this example) and three falling to two for Analyser B with lives of 14 and 15 years respectively.

Such an analysis allows the sensitivity of the findings to be easily tested. Based on real-world operational experience the life of Analyser B has been reported by several large utilities in Europe and the USA to be around 10 years. Consequently, it seems highly unlikely that others will achieve the 15 year life for Analyser B necessary to make it the lowest total cost of ownership.

The scenario can be reversed with the life of Analyser B fixed at 10 years and the life of Analyser A becoming the variable. In this case the question becomes how short does the life of Analyser A have to be for Analyser B to deliver the lowest life cycle cost. The sensitivity study concludes that the life of Analyser A must be less than 12 years for Analyser B to have the lower over all life cycle cost.

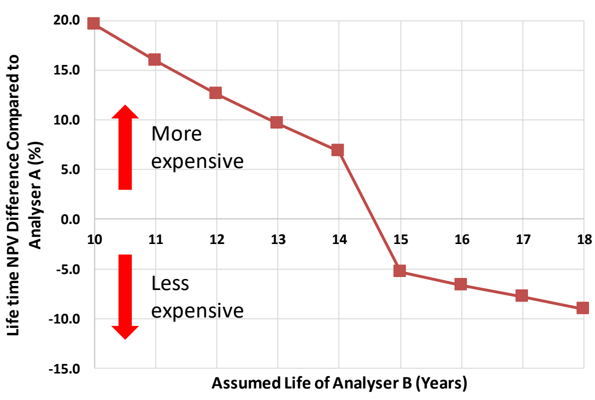

Figure 7: Sensitivity analysis of the effect of Analyser B life on which analyser represents the lowest LLC.

In the case of Analyser B, units have been in service for 10 years. In contrast, although the expected life of Analyser A is 15 years the longest in-service units have been operating for 9 years. There is therefore some uncertainty of what will be the actual life. Nevertheless, the previous calculations show that the life of the analyser would have to be in excess of 20% shorter than the manufacturers expected life for Analyser B to be the lower life cycle cost.

CONCLUSIONS

A simple life cycle cost model has been created to allow the total cost of ownership of online dissolved gas analysers to be calculated. The results show that the cheapest capital cost analyser does not necessarily have the lowest life cycle cost, even when the more expensive analyser requires periodic consumables (e.g. gases for the chromatograph).

This work shows that on-going operation and maintenance costs have a significant impact on the total cost of ownership, and in particular, the number of call outs required to facilitate repairs.

It is important to note that this study does not mean that all infra-red based analysers have a higher life cycle cost than all chromatography based analysers. Each analyser has to be evaluated on its own merit taking account of capital cost, reliability and repair costs, and any necessary consumables.

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